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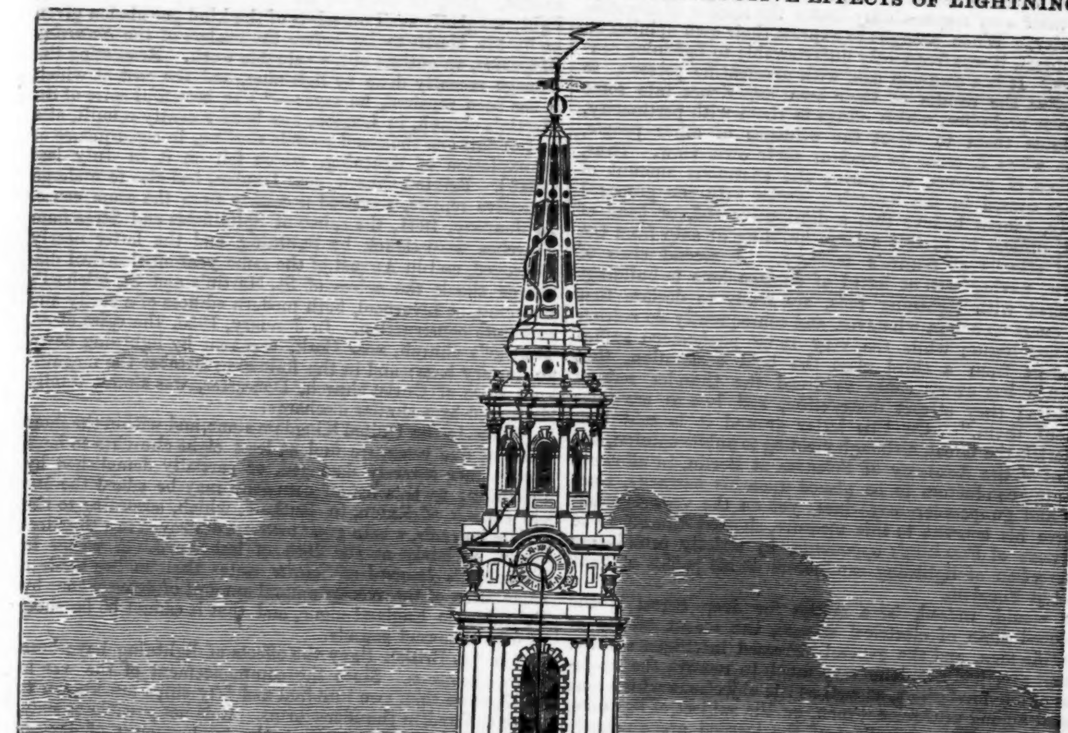
SOME ACCOUNT OF THUNDER-STORMS;
AND ON THE APPLICATION OF LIGHTNING CONDUCTORS TO THE PRESERVATION OF CHURCHES AND OTHER BUILDINGS, AND OF SHIPPING, FROM THE DESTRUCTIVE EFFECTS OF LIGHTNING.



ST. MARTIN'S CHURCH, LONDON; SHOWING THE TRACK OF THE LIGHTNING WHICH FELL ON ITS SPIRE IN THE THUNDER-STORM OF JULY 28, 1842.

SOME ACCOUNT OF THUNDER-STORMS; AND ON LIGHTNING CONDUCTORS.

In one of those scientific notices with which M. Arago enriches the pages of the *Annuaire*, a large number of valuable details are collected on the subject of thunder-storms and lightning conductors. The general ignorance, or, what is worse, the inveterate prejudice which long prevailed among persons most interested in the subject, is there noticed and lamented. Architects, engineers, military and naval men, and citizens of every class, though in their turns experiencing the disasters of thunder-storms, were led to adopt the protective means indicated by science, not so much because they believed them to be efficacious, as because they were glad to place their own responsibility under the shelter of scientific authority. When brought to express their own opinion on the subject, it was frequently unfavourable to lightning conductors. It is a common case with unscientific persons, to generalize the results of their own experience into some dogma or prejudice, which clings to them with pertinacity, and leads them to reject the evidence of other people, except when it tends to confirm their own view. Thus, one class of persons, comparing the enormous amount of damage caused by the lightning stroke with the proposed remedy, cannot believe that a diminutive rod, or band of metal, suffices to protect a large building or ship from the fearful attacks of nature's artillery. A second class of persons, having seen or heard of damage done to buildings furnished with lightning rods, are ready to declare that they exert no action whatever, and consequently do neither good nor harm; while the very same phenomena suffice to extort from a third class the bold declaration, that "Science has every cause to dread the thunder rods of Franklin; they attract destruction, and houses are safer without them." On this latter ground it is said that Frederick the Great, although yielding to public opinion, and to that of the Academy of Sciences at Berlin, in allowing lightning conductors to be placed upon his barracks, arsenals, and gunpowder magazines, yet on the very day that he gave his consent to this measure, showed himself to be a partisan of Franklin's opponents, by strictly prohibiting the erection of lightning conductors at his palace of Sans Souci at Potsdam.

It would, indeed, be a matter for deep regret if the advanced state of electrical science, the recent efforts of scientific men, and the general increased intelligence of the present age, had not done very much to remove the prejudices of our forefathers, as well as the objections which long existed among professional men, on the subject of lightning conductors. The prejudices of the learned are obviously more difficult to deal with than those of the ignorant. We may cure ignorance by imparting sound knowledge; but the man who engrafts a prejudice on his professional knowledge, is willing and able to engage in many a war of words in its defence, and it is only to the voice of public opinion that he eventually yields. Hence it is, that we hail with delight the more enlightened views that are now gaining ground, and which we believe will be materially aided by the recent publication of a clear and concise view of the whole question of lightning conductors, based upon profound knowledge of the principles and conditions on which their efficacy depends, and a practical knowledge of their action, and this, as it respects ships of every size at sea, as well as buildings of every kind on land*. There can be no doubt when the merits of the whole question come to be more generally known, that lightning conductors will be attached to our churches, and other public buildings; that lightning conductors will be attached to our barracks, arsenals, gunpowder magazines, light-houses, &c.; that Government will order Old England's wooden walls to be protected by efficient conductors; and that every merchant will insist upon having his ship similarly protected.

But if prejudice was long an obstacle to the adoption of lightning conductors, indifference has been a greater, for it cannot be denied that most persons are too indifferent on the subject. Indifference, as well as prejudice, has its source in ignorance, and we cannot but hope that the authentic details now so industriously collected, and so admirably digested, will have the effect of exciting a lively interest in a subject which is, indeed, of national importance. The general reader is little aware how much he himself is a sufferer from thunder-storms. Our ships are sailing on every sea, and the sun never sets upon our empire, so that it may, without arrogance, be said that we are exposed to injury from every thunder-storm that visits the earth; the wealth of the nation is being constantly expended in repairing damage which a well regulated system of conductors would entirely obviate, to say nothing of the inconvenience of closing our churches, and public buildings, during the costly but necessary repairs; and the danger to the country in being deprived of the services of ships and men, in times when they may be most needed. But, in order to set this subject in the clearest light, we gladly avail ourselves of the kind permission given us by Mr. Harris to lay before the readers of the *Saturday Magazine*, an outline of his valuable work. Respecting the damage recently done by lightning, and the cost at which it has been repaired, he says:—"The beautiful spire of St. Martin's church, in London, has been recently rebuilt, at a cost of full one thousand pounds sterling, in consequence of an explosion of lightning, which fell on it in July last [1842]. Brixton church, near London, had also to undergo extensive repairs, rendered necessary from the same cause. In January, 1841, the spires of Spitalfields and Streatham churches were struck by lightning, and the latter nearly destroyed, and in August of the same year an electrical discharge shook the spires of St. Martin's and St. Michael's churches, at Liverpool, both modern edifices of a costly and elaborate construction. In January, 1836, the spire of St. Michael's church, near Cork, was rent by lightning down to its very base; and in the following October the magnificent spire of Christ church, Doncaster, was almost totally destroyed by a similar discharge.

"Thus, in the United Kingdom alone, and within the short space of five years, we find at least eight churches to have been either severely damaged, or partially demolished by lightning; to this list of casualties may be added the fine old church of Exton, in Rutland, which, according to the public journals, was in great measure destroyed in a thunder-storm, so lately as the 25th of last April. A writer in Nicholson's *Journal of Science* states that he has made a calculation of the average annual amount of damage done by lightning in England alone, and that it cannot be far short of fifty thousand pounds.

"In the British Navy the effects of lightning have been more disastrous. Since the commencement of the war in 1793, more than two hundred and fifty ships are known to have suffered in thunder-storms. It is not possible to state, with any degree of precision, the total amount of damage done, as all the instances in which ships have suffered cannot be well ascertained: some idea, however, may be formed of it, from the following facts, derived from the official journals of Her Majesty's ships, deposited at the Admiralty. In one hundred and fifty cases, the majority of which occurred between the years 1799 and 1815, nearly one hundred lower masts of line-of-battle ships and frigates, with a corresponding number of topmasts and smaller spars, together with various stores, were wholly or partially destroyed. One ship in eight was set on fire in some part of the rigging or sails; upwards of seventy seamen were killed, and one hundred and thirty-three wounded, exclusive of nineteen cases in which the number of wounded is returned as 'many' or 'several.' In one tenth of these cases the ships were completely disabled, and they were compelled in many instances to leave their stations, and that, too, at a critical period of our history. The expenditure, in these few cases, in the mere material, could not have been far short of one hundred thousand pounds sterling. So that if the whole amount of the loss to the public, in men, in money, and in services of ships could be ascertained, it would necessarily prove to be enormous; more especially when we take into account the expense of the detention and refit of the damaged vessels, the average cost of a single line-of-battle ship to the country being one hundred pounds per diem, and upwards. Now between the years 1809 and 1815, that is to say, within the short period of six years, full thirty sail of the line, and fifteen frigates, were more or less disabled."

Even in time of peace, when a smaller number of ships is required, the accidents from lightning have been many and fatal. About the year 1830, in little more than twelve months, three line-of-battle ships, a frigate, and a brig, were more or less disabled. On the Mediterranean station alone,

* *On the Nature of Thunder-storms, and on the Means of Protecting Buildings and Shipping against the destructive effects of Lightning*, by W. Snow Harris, F.R.S.

between the years 1838 and 1840, eight ships were struck by lightning, and more or less severely damaged. One of them was set on fire. In other parts of the world numerous accidents have also occurred from the same cause. It is also highly probable that many a ship which has been reported as missing, has been destroyed in a thunder-storm, without one of the crew being spared to record her fate.

The damage done to the ships of the East India Company, and to merchant ships generally, has occasioned the destruction of much life and property. So that when we consider the danger to which we are all liable from thunder-storms, whether in the huge war-ship on the ocean, or in the pleasure boat on the river: whether we occupy the palace, or the cottage; the church, or the senate-house; and that this danger is often as sudden and unexpected in its coming as it is fearful in its results, affording no time for deliberation, or the adoption of preventive means, there certainly does seem to be called for the universal adoption of such a system of lightning-conductors as science approves, and of which experience has tested the efficacy.

Section 1.

The Electrical Conditions of a Thunder-storm.

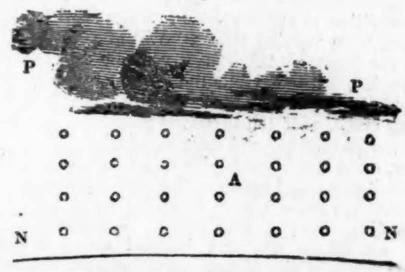
The reader is probably aware that common electricity as obtained from the electrical machine is identical with lightning:—that the grand phenomena of a thunder-storm may all be imitated in miniature, by means of the apparatus of the electrician:—and that although we are unable to understand what electricity is, yet we are not on that account debarred from studying its properties and effects, just in the same way that the various phenomena of light or of heat may be collected and compared without our being able to decide as to their real nature.

In a series of popular articles contained in the *Saturday Magazine*, Vols. XIII. XIV. XV., the properties of common electricity were illustrated. It will not, therefore, be necessary in this place to do more than remind the reader that electricity in its ordinary state of distribution among the particles of matter does not appeal to our senses:—it is then neutral, or quiescent, or in equilibrium, and it is on the disturbance of this equilibrium, that electrical phenomena depend. There is a strong tendency in the electrical agency to remain in, or to regain this state of equilibrium. Electricity is also conducted or transmitted more easily by some bodies than by others;—those bodies which, from whatever cause, afford as it were a good road or path along which the electricity can travel with ease and rapidity, are called *conductors;* while, on the contrary, those bodies which do not easily allow of the transit of electricity are called *non-conductors* or *insulators* of electricity:—thus, the metals are conductors, while all vitreous and resinous substances are non-conductors or insulators. Professor Wheatstone has shown that electricity will travel along a copper wire at the rate of 576,000 miles in a second of time; and the late Mr. Cavendish found the difference between the conducting powers of iron and water to be nearly in the ratio of four hundred millions to one; "that is to say, electricity meets with no more resistance in passing through an iron rod four hundred millions of inches long, than it would meet with in passing through a column of water of the same diameter, only one inch long."

In every electrical disturbance two forces, exactly equal and opposite to each other, are brought into action. These opposite electrical states have been imagined to depend on the presence of two equally powerful, but dissimilar agents, termed the *vitreous* and the *resinous* electricities, from the circumstance of one of them being very commonly produced by the rubbing, or other mode of excitation, of glass, or vitreous substances generally; and the other by the excitation of resin or resinous substances generally. The one is also sometimes called *positive*, and the other *negative* electricity. "There is not, however, any essential difference between them, so far as relates to their action as physical forces: and although, for the sake of perspicuity, they may be considered as positive and negative powers, or as positive or negative electricities; yet it is still to be remembered that one is as much a positive force as the other." These two forces exist both at the same time: "it is found impossible to charge common matter with one of them, without the other appearing somewhere, either in near or distant bodies, just as it is impossible to pull against a fixed point, without eliciting, in that point, an equal and opposite force."

In fig. 1 let P P represent a collection of clouds containing free electricity; N N the earth's surface; and A the intermediate air. If a good conducting substance, such as a rod of metal, connected these clouds with the earth, the electricity would escape from the cloud by conduction merely, and

Fig. 1

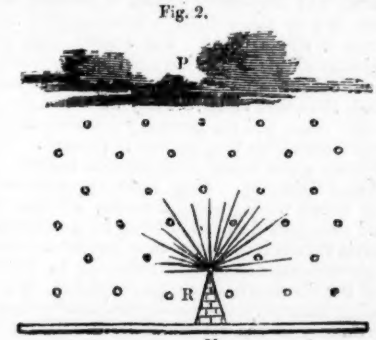


equilibrium would thus be restored: but as a badly conducting substance, viz., the air A, is placed between the cloud and the earth, the earth's surface is thrown into an electrical state of a precisely opposite kind to that of the clouds. This is effected by a force called *induction*.

Such is a very brief view of the electrical conditions of a thunder-storm. The conducting surfaces of the clouds and the earth are the terminating planes of a highly excited mass of air which separates them; and this state of things continues until the electrical excitement of the air has attained its highest pitch, so that any tendency to further excitement renders the air incapable of resisting the tendency of the opposite electrical forces P P N N to combine: the whole system becomes subverted, and a violent reunion of those opposed forces instantly ensues. Such a discharge is generally of a sudden and violent character, and is the cause of the damage to imperfectly conducting bodies on the earth's surface at N N, or in other words, such is the origin of the numerous accidents from lightning.

But it sometimes happens that the discharge assumes a more progressive and quiet form; and gives rise to phenomena which are free from danger. Thus in fig. 2 a pointed

Fig. 2.



metallic rod, R, projects into the highly excited mass of air between the terminating planes P N, the consequence of which is that the particles of air, at the extremity of the rod, become so highly excited as to discharge their electricity upon the next or more remote particles, the electrical condition of which is less intense. The result of this action is a luminous burst of beautifully coloured light, attended by a sort of roaring noise. It is, in fact, a rapid succession of electrical sparks between metal and air. Sometimes the appearance of the brush is changed into that of a star, in which case the discharge is *towards* the pointed conductor, and not *from* it, as in the case of the brush discharge. There is also another species of discharge, termed the glow: it is occasioned by the rapid charge of the air in contact with a metallic rod, which exhibits a beautiful glow of lambent light.

These appearances have at various times excited the fears and superstitions of mankind. Pliny states "that stars settled on the sail-yards and masts of ships with an audible sound: also on the spears of soldiers." Seneca says that the "spears seemed to be on fire in the Roman camp." Cæsar and Livy also mention similar appearances. In more modern times these natural phenomena have excited frequent remark. The French and Spaniards call them St. Elmo's fires; the Italians call them the fires of St. Peter and St. Nicholas; our English sailors call them Comazants.

The identity between common electricity and lightning

may be shown by a variety of striking and popular analogies, which we have not sufficient space to enlarge upon. In proportion as we increase the size and excellence of our electrical apparatus, so are the effects exalted, and their analogies to lightning more closely drawn; and so also are we in a better condition to exhibit those varieties to which lightning is subject, from varying causes. With respect to lightning, "when the discharge takes place very close to the observer, the effect is a brilliant vivid light of momentary duration, intolerable to the eye, and attended by a terrific and sudden whizzing crash, as if ten thousand porcelain jars had fallen on a stone pavement, and were smashed in pieces. When, however, some considerable distance is interposed, the light is more tolerable, and precedes the crash by a sensible time; in this case the noise begins to soften down into a sort of reverberating roar; at still greater distances the reverberations are taken up, and bandied about between the irregular forms of the distant clouds and the surface of the earth, producing what has been termed, in common language, peals of thunder. A similar effect ensues on the earth's surface, during the discharge of cannon, where surrounding objects present irregular sources of reverberation: on the sea, where so few obstacles to the diffusion of sound exist, distant thunder regularly dies away in a sort of sullen silence. The distance of the point of discharge may be estimated by the time which elapses between the flash of lightning and the thunder; since for small distances the progress of light may be taken as instantaneous; sound, on the contrary, has a more sensible duration, being propagated through the air at the rate of eleven hundred feet in a second." Hence, by counting the number of seconds which elapse between the time of seeing the flash and hearing the report, the distance of the thunder-cloud from the observer will be ascertained by multiplying eleven hundred feet by the number of seconds.

Arago distinguishes three kinds of lightning, according to its appearances. First, those luminous discharges characterized by a streak of light, very thin and well defined at the edges; they are not always white, but are sometimes of a violet or purple hue; they have a deviating track of a zig-zag form, and frequently divide, in striking terrestrial objects, into two or more distinct streams, but invariably proceed from a single point. The second kind comprises those luminous effects which have not any apparent depth, but expand over a vast surface. They are frequently coloured red, blue, and violet. They have not the activity of the former class, and are generally confined to the edges of the cloud from which they appear to proceed. The third class comprises those more concentrated masses of light, called globular lightning. They have a progressive motion, and appear to last during many seconds; whereas the long zig-zag and expanded flashes exist but for a moment.

Mr. Harris thinks it is more than probable "that many of these phenomena are at last reducible to the common progress of the disruptive discharge, modified by the quantity of passing electricity, the density and condition of the air, and the brilliancy of the attendant light. When the state of the atmosphere is such that a moderately intense discharge can proceed in an occasionally deviating zig-zag line, the great nucleus, or head of the discharge, becomes drawn out, as it were, into a line of light visible through the whole track; and if the discharge divides on approaching terrestrial objects, we have what sailors call *forked lightning*. If it does not divide, but exhibits a long rippling line, with but little deviation, then they call it *chain lightning*. What sailors term *sheet lightning*, is the light of a vivid discharge reflected from the surfaces of distant clouds, the spark itself being concealed by a dense intermediate mass of cloud, behind which the discharge has taken place. In this way an extensive range of cloud may appear in a blaze of light, producing a truly sublime effect. The appearance termed globular lightning, may be the result of similar discharges; it is no doubt always attended by a diffusely luminous track; this may, however, be completely eclipsed in the mind of the observer, by the great concentration and density of the discharge, in the points immediately through which it continues to force its way, and where the condensation of the air immediately before it is often extremely great. It is this intensely illuminated point which gives the notion of globular discharge; and it is clear, from the circumference of air which may become illuminated, the apparent diameter will be often great."

The appearances termed *fire balls* have often been described. On the 4th November, 1749, Mr. Chalmers, on board the *Montague*, of seventy-four guns, "whilst taking an observation on the quarter deck, was requested by one of the quarter-masters to look to windward; upon which he observed a large ball of blue fire rolling along on the surface of the water, as big as a mill-stone, at about three miles distance. Before they could raise the main-tack, the ball had reached within forty yards of the main-chains, when it rose perpendicularly with a fearful explosion, and shattered the main top-mast in pieces." In an account of the storm on the Malvern hills, in June, 1826, in which two young ladies were struck dead, it is stated that the electric discharge "appeared as a mass of fire, rolling along the hill towards the building in which the party had taken shelter." It is not easy to explain these appearances, by reference to principles which apply to the ordinary electric spark; this spark moves at the amazing rate of 576,000 miles in a second of time, and its light has a less duration than the one-millionth part of a second. It is therefore impossible for the discharge to appear under the form of a ball of fire; it would be a transient line of light. Mr. Harris supposes, that, in many cases in which distinct balls of fire of sensible duration have been perceived, the appearance has resulted from the species of brush or glow discharge already described, and which may often precede the main shock;—that the greater number of discharges described as globular lightning are most probably nothing more than a vivid and dense electrical spark in the act of breaking through the air,—which coming suddenly on the eye, and again vanishing in an extremely small portion of time, has been designated a ball of light.

It is a common observation that when the electric discharge occurs in a confined space, such as in a room or on ship-board below decks, it leaves behind it a sulphurous odour. This it is difficult to explain, but there is no doubt a tendency of the electrical discharge to drag into its path light conducting substances, such as smoke, free vapour, or other conducting matter floating in the air, which facilitate its progress, and enable it to strike through greater distances than could otherwise be traversed. There is also little doubt that conducting matter, when dragged into the lightning's path, would be intensely heated and decomposed, and this may, in some degree, explain the sulphurous odour.

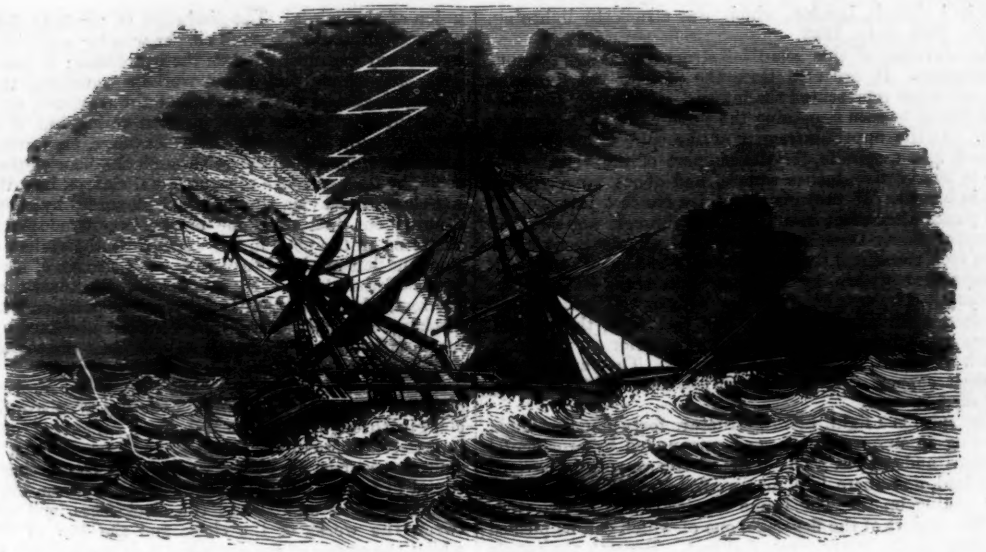
Section 2.

Phenomena of Thunder-storms.

The general condition of a thunder-storm has been already explained to consist of the charging and discharging of a stratum of air intermediate between the masses of cloud and the earth, or otherwise intermediate between two masses of clouds in opposite electric states.

"The first appearance of a thunder-storm generally happens when there is little or no wind; there is one dense cloud or more, increasing very fast in size, and rising into the higher regions of the air. The lower surface is black, and nearly level, but the upper is finely arched and well-defined. Many of these clouds seem piled one over another, all arched in the same way, but they keep continually uniting, swelling, and extending their arches. At the time of the rising of this cloud the atmosphere is generally full of a great number of separate clouds of whimsical and irregular shapes, and apparently motionless. All these upon the appearance of the thunder-cloud draw towards it, become more uniform in their shape, and at length form with it one common mass. Sometimes the thunder-cloud will swell very fast without the conjunction of such clouds, and when it is grown to a great size, its lower surface is frequently ragged, and swells into large protuberances which bend uniformly toward the earth; sometimes one whole side of the cloud has an inclination towards the earth. When the eye is under the thunder-cloud, it is at last seen to darken fearfully, and a number of small clouds, the origin of which is never detected, drive about it in uncertain directions. Rain and hail about this time fall in abundance. During the swelling and extension of the cloud over a large tract of country, lightning darts through its mass, and at length strikes towards the earth in opposite places; the longer the lightning continues, the rarer the cloud becomes, till at length it breaks up, and shows a clear sky."

A thunder-storm at sea, in the Bay of Honduras, is thus noticed by Captain Ward whilst he was in command of His Majesty's ship *Pelican*, in the autumn of 1806. "The night was nearly calm, and the heat oppressive; heavy black clouds, intensely charged with the electric fluid, overspread the earth, and about midnight, after a little whirl of wind, began to approach it. A discharge of light-



THE ENGLISH FRIGATE THISBE, STRUCK BY LIGHTNING NEAR THE SCILLY ISLES.

ning, of the most splendid and at the same time most awful character, speedily ensued. The electric fluid seemed to pour down upon the earth and sea in repeated streams, occasionally illuminating everything about us with a brilliancy surpassing noon-day, but leaving us at the next instant in pitchy darkness. This fearful display, attended by roaring peals of thunder, lasted about an hour, during which time one of the discharges fell on our main-royal masthead, shivered it, together with the top-gallant mast and top-mast, in atoms, scattering the fragments to an immense distance, so that not a piece of any size could be found. The discharge continued its course with damage along the mainmast in an irregular spiral form down to the very heel and step of the mast, where it disappeared."

A most awful storm has been described by a passenger in the splendid American packet-ship *New York*, which was struck and damaged by lightning in the Gulf Stream, on the 19th April, 1827, in her passage from New York to Liverpool:—"About half-past five in the morning, being in our berths, we were roused by a sound like the report of heavy cannon close to our ears. In a moment we were all out. From the deck the word was quickly passed that the ship had been struck by lightning, and was on fire. Every one ran on deck; there, all the elements were in violent commotion: it had been broad day, but so dark, so dense, and so close upon us were the clouds, that they produced almost the obscurity of night. There was just sufficient light to give a bold relief to every object in the appalling scene; the rain poured down in torrents, mingled with hailstones as large as filberts: these lay upon the deck nearly an inch thick; over-head blazed the lightning on all sides, accompanied by simultaneous reports; the sea ran mountains high, and the ship was tossed rapidly from one sea to another. One appearance was peculiarly remarkable: the temperature of the water was 74° of Fahrenheit, whilst that of the atmosphere was only 48°. This caused by evaporation and condensation immense clouds of vapour, which, ascending in columns all around us, exhibited the appearance of innumerable pillars supporting a massive canopy of clouds. In all directions might be seen water-spouts, which, rising fearfully to the clouds, seemed actually to present to the eye a combination of all the elements for the destruction of everything on the face of the deep."

The quantity of electricity disengaged during a thunder-storm does not appear to be so great in relation to conducting bodies as is generally supposed. We are accustomed to judge of the quantity of electricity present by very deceptive effects,—the light of the spark, the noise and expansive force of the discharge, and by the damage done to imperfectly conducting matter. The effects produced by an electrical machine and an electrical battery prove that comparatively very small quantities of electricity can do much of the work of the lightning stroke. Van Marum by means of his great battery rent boxwood in pieces; melted various metals, and dispersed them in all directions. With such effects as these produced by the hand of man, it does not seem necessary very greatly to multiply the quantity of electricity employed in Nature's battery during a thunder-storm. It is doubtful whether any quantity of electricity ever discharged in a single flash of lightning has been sufficient to melt a copper rod a foot in length, and three-fourths of an inch in diameter.

The masses of cloud which form one of the terminating planes of the electrified system, do not attain so great an altitude as their horizontal extent. They frequently extend over a large tract of country, producing almost simultaneous discharges in various places. Travellers in mountainous regions, frequently describe the thunder-clouds, and the thunder rolling beneath them, while fair weather is smiling above. Admiral Ross states that the storm which shivered the masts of the *Désirée* in Port Antonio, Jamaica, in 1803, was seen by an observer from an adjacent hill, during a fine night with the stars shining brightly.

An attentive examination of the numerous recorded instances in which buildings and ships have been damaged by lightning, will generally enable any one to trace the course of the discharge. It will always be found that this course is through a line, or lines which oppose the least resistance to the passage of the electricity to the earth. "Both space and time are, as it were, economized in the restoration of the electrical equilibrium; for however small we assume the duration or the discharge, or the distance through which it strikes, both these quantities would become still less, were other lines of transit found of still less resistance. This is the leading phenomenon of all disruptive discharges; the electrical agency seizes upon such bodies as lie convenient and ready for its purpose, absolutely avoiding other bodies, however near, from which it can receive no assistance. And it may be further observed, as a most wonderful and interesting fact, that at the instant before the explosion takes place, the stream of electricity, in the act of moving to restore the equilibrium of distribution, feels its way, as it were, in advance, and absolutely marks out the course it is about to take. There is, in fact, a species of inductive action impressed upon bodies happening to lie in the line or lines of least resistance, and which, as it were, by a sort of foresight, determine the course of the discharge. Its progress, therefore, is not, as many imagine, left to the chances of the instant, to be, as it were, attracted or drawn aside by metallic bodies at any given point; nothing of the kind ever happens. The whole course of a flash of lightning is already fixed and settled, before the charge takes place."

Since the two terminating planes of a great electrical disturbance may extend over many square miles of cloud, and of sea and land immediately beneath it, a building or a ship is evidently a mere point, incapable of acting exclusively on a thunder-cloud. A building or a ship is struck, when from its position it facilitates the neutralization of the electrical forces in a given direction, or, in other words, when it forms a portion of the line of least resistance between the cloud and the earth. Such was the position of St.

Martin's church, London, which was struck by lightning, on the 28th July, 1842.

An elevation of this beautiful structure is given in our frontispiece. In order to trace the path of the lightning our artist has represented the internal structure of the spire as it would be seen supposing the stone-work to be transparent. At the upper extremity of the spire is an iron rod formed into a spindle, for the support of the vane. This rod is nearly five inches square, and about twenty-seven feet in length. It projects about twelve feet into the air, and passes fifteen feet into the spire, through a gilded ball of copper thirty-three inches in diameter, and one-sixteenth of an inch thick, and through two solid blocks of stone. It is supported within by a strong iron cross let into the masonry. The weight of the bar is about 12¾ cwt., and its extreme point about two hundred feet from the ground. There are other iron crosses in the interior of the spire, which serve as cramps to the masonry. The vane is made of sheet copper, well gilded, and is about eight feet long, and six feet wide.

The spire is a light, hollow structure forty-four feet high, standing on an open cupola, and surrounded by ornamental columns and arches. The floor of this cupola is covered with lead, and there is a massive frame-work of wood and iron resting on it. The frame is constructed in two parts for the support of the flagstaffs, one of which can be pushed out clear of the tower when required. Beneath the cupola is the dial-room containing the iron spindles of the clock-faces. The figures marking the hours constitute portions of the stone facing without, and surround the recesses of the circles forming the centre of the dials: these circles are formed of shutters of wood and iron, in eight divisions, and are painted black. The four cross rods carrying the hour and minute hands of each dial, are supported in the middle of the dial-room without touching the walls. Under the dial-room is the belfry containing the bells, which are suspended in frames in the usual way, and weigh from five to thirty-one cwt. Beneath the belfry is the clock-room containing the works of the clock supported in a massive iron frame fixed to the floor; an iron rod about three-fourths of an inch in diameter, and forty-six feet long, passes from the works of the clock, through the belfry to the spindles, by which the requisite motion is conveyed to the hands on the dial-plates; this rod is constructed of several pieces united by brass screws: it is cased in wood, and passes within ten inches of the lip of each bell. Beneath the clock-room is the ringing-chamber, having windows with iron frames; immediately without these is the lead covering the roof. These particulars will enable the reader to understand the phenomena connected with the explosion.

The first point struck was the point of the vane-spindle; the discharge passed into the spire through the iron rod, without any damage to the blocks of stone immediately surrounding it, and without affecting the copper ball or the gilding of the vane. The only effect produced was the disturbance of a little cement about the ball, which seemed as if shook by a violent concussion of the air. At the cross the discharge left the vane-rod, and passed into the masonry of the spire, starting an angle stone, and from thence so damaged the spire in passing down it, as to leave the whole in a tottering state. Two blocks of stone were thrown completely out of their places, and fell through the roof into the church, the joints of the spire were all loosened, and its general surface contorted. Two other stones were quite dislocated; if these had also been thrown out, the whole of the upper portion of the spire must have fallen. From the base of the spire the discharge passed with destructive violence on the frame-work of the flagstaff, the wood-work of which was shivered, and then getting hold of the lead on the cupola, it forced a passage to a metal clamp within the masonry, where it tore up and fractured a large flat stone, and turned it completely over; in this way it passed to the nearest points outside the tower leading to the north and west dials: upon these the discharge divided, and fell upon the gilded letters XI. and XII., the gold of which, on the west dial more especially, was burnt up and blackened. From these points it exploded upon the minute-hand, where it also blackened the gold, and damaged the points of the hands. From this, it passed along the spindles of the north and west dials into the dial-room, without affecting the surrounding parts, and seizing the iron rod connecting the spindles with the clockworks, passed safely within its case of wood, and between the masses of metal in the bells down to the works of the clock: the only traces left in this course were a little fusion of the brass screws and of the iron at the union of the joints. The discharge, on reaching the works of the clock, melted a small copper wire by which the lever handle key was suspended on the iron frame: it now spread over the wheels and other works, magnetized the steel pivots, blackened the silver face of the regulator, and burst open the door of the outer wooden casing, but it did not, however, stop the clock. The discharge, on leaving these conductors, forced a passage through the floor of the clock-room, by the assistance of some metal clamps, into the ringing-chamber, leaving the floor as if blown up by gunpowder. Coming out just over one of the iron window-frames, it shattered all the glass in the window by the violent concussion, and left marks of fusion on small streaks of lead in the joints of the stones. By this course, it reached the lead of the roof, which was slightly fused at the point on which the discharge first fell. After this it became dispersed upon the earth without further damage to the large masses of metal and pipes connecting the roof with the ground.

It is impossible, continues Mr. Harris, to conceive a case giving a better insight into the nature of disruptive discharges through an accidental arrangement of good and imperfect conductors. It must be observed that all the damage occurred in points where good conducting matter ceased to be continued, as, for example, between the termination of the vane-rod and the clock-faces, and again between the works of the clock and the lead of the roof, whilst the course of the discharge is so marked and definite, and so independent of bodies not contributing to assist its progress, that it actually passed down the small iron rod within a few inches of the bells, without affecting in any way these large metallic masses, or disturbing the wooden case by which the rod was surrounded. The discharge, in passing upon the dials, selected the north and west faces as affording the easiest line of transit, as the minute hands only could contribute to the conduction, being at the time in a position to transmit it to the centre of the dial, these only were affected; the hour hands, although continuous to the lower part of the dials, were evidently without the line of action: the course of the discharge, therefore, became diverted at right angles nearly from the line of the hands, in order to pass upon the line of metals within the tower. In this, as in all other instances of damage to buildings or ships by lightning, the course of the electrical discharge is similarly determined through points which offer the least resistance to its progress, and the damage invariably occurs between detached masses of metal.

The illustration at p. 85 represents the condition of the *Thisbe*, an English frigate, struck by lightning in January, 1786, near the Scilly Isles, during her passage from Lisbon. The weather at the time was squally, so that the ship was hove to under storm stay-sails. The electrical discharge, after disabling several of the crew, struck on the mainmast, and set fire to the rigging and sails; it also struck and shivered the foremast. To get clear of the burning mass, the master cut one of the lanyards of the main shrouds to windward, when the force of the gale carried the whole over the side, with the mizen-topmast; the fore-topmast soon followed, leaving the ship almost a total wreck.

Section 3.

On Lightning Conductors.

Since the damage by lightning to buildings and ships happens only in those places where good conductors of electricity are absent, it occurred to Franklin to provide a continuous line of conduction, or in other words, a good road whereby the lightning might travel to the earth without exploding, or otherwise endangering the structure.

But it must not be forgotten that a building and a ship are already conductors of an imperfect kind; but that metal is so vastly better a conductor than stone, brick, or wood, that when an edifice is struck by lightning the line of least resistance is always to be found through any detached masses of metal that may have been used in the building, and that in order to get at these the lightning tears, rends, twists, and otherwise damages the stone, brick, or wood; in fact the lightning, under such circumstances, acts as a powerful mechanical force, producing effects exactly similar to those of gunpowder ignited in a confined space. An iron steam boat, or a man in armour, is perfectly safe in a thunder-storm, on account of the great conducting power of the metal. If, therefore, in a building or a ship, all the metallic masses, in the spaces where the damage ensues, be united into a continuous conducting train, a sufficient degree of conducting power is supplied for their safety.

Metals vary in conducting power as well as building materials, and a lightning rod should evidently be made of the best conducting metal. For this purpose copper is usually preferred; it conducts full five times better than iron, and twelve times better than lead. The rod may be in the form of a tube or pipe, it should expose as large a surface as possible, consistent with strength and durability. Its upper extremity should be pointed and project freely into the air. Where metallic vane-spindles, or other points, exist, it may commence from these. It should be led as directly as possible along the building, and be fixed close to the walls, and not at a short distance from them. It should terminate immediately under the surface of the ground in two or more branches, passing if possible into a spring of water, a drain, or some other conducting channel. It should be united with all the great masses of metal in its vicinity, which offer other possible lines of discharge, so that the lightning cannot find its way to the ground by any circuit of which the conductor does not form a portion.

It is of the utmost importance that the conductor be of sufficient size to carry off the lightning, without suffering from its heating effects. It has been found that the heat developed by a passing shock is four times as great when the quantity of electricity is doubled, and only one-fourth as great when the diameter of the wire is doubled, so that a metallic rod of twice the diameter conducts twice the quantity of electricity with the same developement of heat.

The consequences arising from the employment of small and otherwise inefficient lightning conductors are well illustrated by a variety of instructive cases, cited by Mr. Harris. Our space will allow us to quote only one, which is that of the New York packet already noticed. "In this case the discharge fell on a pointed iron rod four feet long, and half an inch in diameter; some few inches only of the rod near its point were melted; the linked iron chain which descended from this rod to the water, about a quarter of an inch in diameter, was knocked in pieces by the expansive force of the shock, and some of the links fused. The flash of lightning not only melted some of the links, but 'caused them to burn like a taper.' 'The melted iron fell in glowing drops upon the deck, which was instantly set on fire wherever the burning matter fell.' 'Such was the violence of the shock, that the ship recoiled, or, in ea phrase, lurched so strongly, as to throw down the people on the deck.' The results of a great natural experiment are here presented to us, and we see that an iron rod of half an inch in diameter remained safe from a flash which fused and destroyed a chain of about one-half of its dimensions."

To the question, how far does the protecting power of a lightning rod extend? it is not easy to return a satisfactory answer. Past experience on the operation of conductors on discharges of lightning, tends to show that they have no influence whatever in determining the course of such discharges, further than arises out of the circumstance of the easy line of conduction which they furnish. It has been popularly supposed, that to convey a conducting wire from the highest point of a building to the earth, would suffice, not only for the protection of that building, but also of a considerable surrounding space, and that to attach a wire or chain to the mainmast of a ship, would ensure the ship from the attacks of lightning. It is proved, however, by experience, that buildings and ships furnished with such lightning rods may be struck, and this circumstance, perhaps more than any other, has contributed to strengthen the prejudices against lightning conductors. People do not inquire whether the conductor was an efficient one; nor whether the damage would not have been greater if no conductor at all had been present: that a building or ship furnished with a conductor has been struck by lightning, is a sufficient reason for them to make the very long jump to the conclusion, that lightning conductors "attract destruction, and that houses and ships are safer without, than with them." The view taken of electrical discharges from the atmosphere, (see fig. 1,) is abundantly confirmed by the accidents which have occurred to buildings and ships furnished with lightning rods, and shows how unsafe it is in ships to trust to a conductor on one of the masts only; and how necessary it is to ranges of buildings to distribute connected conducting lines, and to unite these lines with pointed conductors.

Having once agreed that lightning conductors are necessary to the safety of all lofty erections on land, their application is easy enough. With the very clear and concise directions and drawings given in the work before us, the architect, the builder, or indeed any one, with the assistance of a few workmen, may make an efficient conductor, and attach it properly to the building required to be protected; and when once fixed it requires no further attention. Such is by no means the case with respect to ships, because the masts and rigging, the only parts to which conductors can be applied, are subject to frequent change and derangement:—the masts consist of distinct portions, which it is often requisite to move one on the other, and sometimes to remove altogether. Therefore to construct and apply a conductor to a ship, such as may be permanently fixed, and require no handling or attention on the part of the crew, would seem at first view, difficult, if not impossible.

The first lightning conductors for ships consisted of long links of small iron rod, attached to the head of the mast, and carried from thence over the ship's side to the sea. In the year 1762, long links of copper rod were substituted: they were attached to a hempen line, and directed to be applied as before. One such conductor was supplied to each of His Majesty's ships: it was packed in a box, and directed to be used as occasion required. "Such a conductor would, without doubt, go far in defending a vessel against a stroke of lightning, provided it was fairly in its place, and that the electrical discharge fell directly on the mast to which it was applied. A ship, however, being constantly exposed to heavy gales, and the masts and rigging always open to the operation of violent mechanical forces, renders the use of such chains not only difficult but extremely precarious. Hence they have fallen into disuse, and our shipping has remained exposed to the ravages of lightning; as is fully proved by the vast amount of damage so frequently occurring." There is also an electrical disadvantage in the use of linked, or chain conductors. The expansive and heating effect of the lightning is so powerful as often to break the link, and fuse the metal. In the year 1824, the French employed conductors of wires twisted together in the form of cordage. They were applied along the rigging from the vane-rod to the ship's side, where they were connected with a plate reaching to the sea. But there are numerous objections to conductors of such small dimensions, applied as rigging, and dependent on the sailors for their due application. Without insisting on their inefficiency as mere conductors, the circumstance of arranging, displacing, and altering their position according to the varying circumstances of the ship, is of itself a sufficient objection. "Let any one picture to himself a heavy gale, a pitchy dark night, squalls of wind with lightning and thunder,—a very common case,—and that it becomes necessary to make certain changes in the masts and sails; as, for example, to strike the top-gallant masts and get them on deck." In this case the men are necessarily exposed aloft, and have to disengage the conductor and the truck to which it is attached. If, at the time, the ship be struck by lightning, the men must either be killed or seriously hurt. Indeed there are many cases to show the great danger of handling such conductors in thunder-storms. Three seamen, in the act of applying a linked conductor on board one of the American ships-of-war in the Mississipi, were struck dead. These moveable conductors, when in their places, being always in the way, to the great annoyance of the seamen, fall into disrepute, so that it often happens that when the conductor is most wanted it remains packed up in its box below. Such was the case when the packet-ship *New York* was struck by lightning the first time, and it was only got out just in time to parry a second discharge, which, however, shook it to pieces.

These and other objections to conductors applied as rigging are fully and fairly stated by Mr. Harris; they led him to a careful investigation of the whole subject, which ended in the invention of a system of conductors for shipping, under a form so capacious and so permanently fixed, as to render them an integral part of the vessel, and independent of the crew under all circumstances. According to his plan the masts themselves are converted into lightning conductors, "by incorporating with them a double set of copper plates in such a way as to produce an elastic metallic line along their surface, capable of resisting any strain which the spars themselves could support; and, finally, to connect these plates with bands of copper leading through the side under the deck-beams, and with the large bolts leading through the keels and keelson; and including, by other connections, all the principal metallic masses employed in the construction of the hull; thus rendering the ship quite safe from any discharge of lightning which would be likely to fall upon it, by bringing the whole fabric as nearly as possible under the conditions most favourable to perfect security."

This method being recommended to the Lords of the Admiralty, their Lordships were so impressed with its beauty and importance that, with the sanction of the House of Commons, they appointed a Committee of naval and scientific men to investigate the merits of the method, and the subject of lightning conductors generally. In the official report of this Committee it is stated, that any explosion of lightning falling on a ship fitted with Mr. Harris's conductors would disappear entirely at the mast-head, and consequently all intermediate explosion or damage, such as commonly occurs, would be completely avoided:—that the system was efficient for every position or condition of the masts and hull; and that since the year 1830, it had amply borne the test of experience in many of Her Majesty's ships.

In the volume before us is a detailed description of these conductors, illustrated by drawings, togeth-r with the modes of applying them to ships, whether for war, or the merchant service. These details are too technical for the general reader, who is interested rather in results than processes. We are therefore disposed to lay before him the account of a beautiful experiment, invented by Mr. Harris, illustrative of the efficacy of his conductors in receiving an electrical discharge, and conveying it safely and silently into the sea. This experiment, together with many others, was performed in August, 1842, at Chatham, before many of the Lords of the Admiralty, and a numerous party of official, military, and naval men. The experiments were conducted in the upper story of one of the lofty storehouses in the dockyard. The Daphne corvette, of 18 guns, (her masts being fitted with the new conductors,) was moored in the middle of the Medway, and a boat, containing a loaded nine-pounder gun, was anchored about mid-way between the ship and the shore. At the top of the spindle of the vane at the mast-head of the Daphne was a cup filled with gunpowder: a similar cup of gunpowder was placed over, and connected with, the touch-hole of the gun in the boat. In the storehouse was a powerful electrical apparatus. A copper wire was led from the positive side of an electrical battery to an exploding point in the cup of gunpowder at the mast-head; and another wire from the negative side, to another exploding point in the cup of gunpowder over the touch-hole of the gun, which was at the same time connected with the sea by a short length of wire leading from the touch-hole of the gun over the side of the boat, into the water. There was no connection between the ship and the boat, except by means of the water on which they both floated.

The object of this arrangement was to show that immediately an electrical discharge reached the mast-head, it passed down to and was dispersed in the water, by means of the continuous line of conductors. This was proved in the following manner:—the electric battery in the storehouse was discharged, the discharge passed along the copper wire from the metallic plate on the interior of the jar to the masthead; its presence there was rendered apparent by the ignition of the gunpowder in the cup; it passed thence down the conductor on the mast into the hull of the ship, and along the conductors on the hull into the sea. That it had arrived in the sea was proved by the ignition of the powder over the touch-hole of the nine-pounder gun in the boat, and the consequent discharge of the gun; because the only means by which this gunpowder could be ignited was the passage of the electricity up the short copper wire which connected the touch-hole of the gun with the sea. So that not only must the electric fluid have arrived in the sea, but it must have passed through it to this short copper wire in the boat. It need scarcely be added that the results which have occupied us so long in describing were produced in an instant: for no sooner was the electricity set free than it ignited the powder at the masthead, and fired the gun in the boat; thus proving most satisfactorily that the instant the explosion arrived at the vane-spindle, that same instant did the conductors clear it of the ship and transmit it to the water.

A further proof of the efficacy of these conductors is afforded by the fact that ships fitted with them have, during the last fourteen years, navigated almost every clime, and have been frequently exposed to thunder-storms and the lightning's stroke, and have yet remained uninjured; for the lightning is no longer to them a terrific agent, active to destroy, but is reduced to a harmless and insensible current of momentary duration, running down the conductor into the sea, as water would run down a pipe placed so as to conduct it. Indeed the reports given by different officers of the circumstances observed when heavy discharges of lightning fell on the masts, coincide in an interesting manner. They all agree in the fact that their ships had been struck by lightning without any damage resulting; and also that the discharge was attended by a whizzing noise, and by a luminous stream along the conductor.

In closing our remarks we must again allude to the popular error, that conductors attract lightning to a ship, and that in larger quantities than they can convey away. The most elementary notion of the electrical conditions of a thunder-storm suffices to prove that "the action of a pointed lightning-conductor is purely passive. It is rather the patient than the agent, and can no more be said to attract or invite a discharge of lightning, than a water-course can be said to attract the water which flows through it at the time of heavy rain;" and even supposing that a lightning rod did possess an attractive power, it would be an absurdity to suppose that it attracted more lightning than it could conduct; because any attraction which it might be supposed to possess, would depend altogether on its conducting power. It was proved long ago, that no more lightning ever falls upon a conductor than it can transmit up to its point of fusion; and on this point it may be observed, that Mr. Harris's conductors are so substantial that all danger from the heating effects of the lightning is removed.

It may, perhaps, be interesting to quote at full the evidence of one of the officers alluded to above. We select that of Captain Sullivan, R.N. who describes a flash of lightning which fell on Her Majesty's ship *Beagle* at Monte Video, and which he witnessed during his period of duty on deck. "Having," says he, "been on board His Majesty's ship *Thetis* at Rio de Janeiro a few years since, when her fore-mast was entirely destroyed by lightning, my attention was always very particularly directed to approaching electrical storms, and especially on the occasion now alluded to, as the storm was unusually severe. The flashes succeeded each other in rapid succession, and were gradually approaching, and as I was watching aloft, the ship became apparently wrapt in a blaze of fire, accompanied by a simultaneous crash which was equal, if not superior, to the shock I felt in the *Thetis*. One of the electrical clouds by which we were surrounded had burst on the vessel, and as the mainmast at the instant appeared to be a mass of fire, I felt certain that the lightning had passed down the conductor on that mast. The vessel shook under the explosion, and an unusual tremulous motion could be distinctly felt. As soon as I had recovered from the surprise of the moment, I ran below to state what had happened, and to see if the conductors had been effected, when just as I entered the gun-room, Mr. Rowlett, the purser, ran out of his cabin (along the beam of which a main branch of the conductor passed) and said he was sure the lightning had passed along the conductor, for at the moment of the shock he heard a sound like rushing water along the beam. Not the slightest ill consequence was experienced, and I cannot refrain from expressing my conviction that, but for the conductor, the results would have been serious."

It seems necessary, in conclusion, to say a few words respecting the cost to the nation of this system of conductors, and on this subject the statement by Mr. Harris is most satisfactory. "The method of fixing the plates, now adopted in Her Majesty's dock-yards, will be found extremely expeditious and easy, whilst the expense bears a very small proportion to the value of the ship, and quite vanishes when we consider how important is the protection afforded. The cost of a first-rate, with all her stores, is not less than 170,000*l.*; she carries full nine hundred men, and she is intended for the defence of one of the greatest maritime nations which has ever existed. Now, the protection of this splendid machine against one of the most fearful calamities to which she is exposed, may be attained at a cost of less than 100*l.*, *i. e.*, the expense of labour in fixing the conductors to the ship, and the loss upon the wear of the copper material, which is always reconvertible, and of a constant value. Her Majesty's navy once furnished with such conductors, as an integral part of the ship, little or no further expense will be requisite, as the hulls will be always ready to receive masts fitted with the same conductors which have been already used in other ships, whose services have for the time ceased; it is hence a mere affair of transfer from ship to ship."

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